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(54) IMPROVEMENTS IN OR RELATING TO BUILDING CONSTRUCTION

(71) I, KOLBJORN SAETHER, of 934 Linden Avenue, Wilmette, Illinois, United States of America, a subject of the King of Norway, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to multi-story building construction and more particulary to precast building construction involving the in situ casting of concrete slabs one upon another in the total number required and then elevating the slabs to and mounting them permanently in their intended positions in the building.

Building construction utilizing reinforced or post-tensioned concrete deck or floor slabs is now a reasonably well developed art as represented in U.S. Patents Nos. 2,686,420 entitled "SLAB LIFTING APPARATUS" and 2,720,017 entitled "METHOD OF ERECTING BUILDINGS". According to those patents permanent steel supporting columns are erected for the intended building, concrete slabs are poured in situ one upon another about and between the columns with attachment collars fixed in the slabs and engaged about the respective columns. Slab-lifting jacks are mounted on the tops of the columns with threaded tension rods depending therefrom and attached to successive batches of two or three slabs which are successively raised by temporarily supporting the uppermost batches of slabs while the lower batches are raised to respective positions and the successive lowermost slabs are permanently attached to the columns by securing their collars in place. The collars serve as guides for the slabs along the columns as well as ultimate means through which the slabs are secured to the columns.

The slab-lifting jacks have an arrangement of respective hydraulic jacks mounted between a holding yoke and a lifting yoke, the jacks raising their lifting yokes by predetermined increments such as in a one-half inch stroke by hydraulic power, thereby correspondingly raising the lifting rods through the holding yoke. Holding nuts are run down the threaded rods onto the holding yoke while the lifting yoke is lowered and take-up nuts run down the upper extensions of the rods onto the lifting yoke, and the cycle repeated. In this manner the heavy loads of the slabs are inched upwardly. At least to the extent of details of the slab-lifting jacks and their mechanical and hydraulic operation, the disclosures of the aforesaid U.S. patents are incorporated herein by reference as is also the disclosure of U.S. Patent No. 2,758,467.

One of the disadvantages of prior constructions has resided in the necessity for erection of supporting columns before pouring or casting the concrete slabs, wherein the columns are obviously obstructions preventing the use of fully automated equipment, but requiring a great deal of manual labor. Further, because the slabs are mounted on the columns, attachment collars must be secured in the slabs about the respective columns requiring tie-in with the reinforcement, and placing limitations upon location of the reinforcement within the slabs.

The prior construction has also placed definite limitations architecturally, being quite restrictive on the architectural layouts due to the need for efficient location of the supporting columns. The best location for the columns is somewhere inside the edge of the slab and away from the slab corners. This results in great architectural conflicts because of the permanent location of such columns. In addition, fireproofing codes require that the steel columns be fireproofed.

In the permanent column arrangement mounting of the lifting jacks directly on top of the columns creates certain problems. The tall unbraced tower-like columns presented certain lateral instability hazards and thus severe limitation upon the weight and thus the number of slabs that could be lifted. Then, it has been necessary where column extensions are employed to remove the lift jacks from the top of the lower column, and

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lift the same to the top of the extension column after the latter has been secured in place on top of the lower column.

According to one aspect of the present invention, there is provided a method of constructing a multi-story building, comprising pre-forming on a ground-supported base a stack of horizontal slabs one upon the other and of a length and width to cover a building area, providing in each of said slabs a plurality of openings vertically aligned in the stack, erecting in said openings ground-supported lifting columns, mounting lifting apparatus on said columns, operating said apparatus to lift said stack of slabs along said columns until the lowest slab in the stack has reached a desired elevation above said base, supporting said lowest slab at said desired elevation on said columns and detaching it from the stack and said lifting apparatus, further operating said lifting apparatus on said columns to lift the remainder of the stack from said column-supported lowest slab while it is held at said desired elevation, while said remainder of the stack is undergoing further lifting by said apparatus erecting building substructure independent of said columns under said lowest slab to provide ultimate support therefor, releasing said lowest slab from said columns on to said substructure for full support by said substructure, repeating the foregoing procedure with each succeeding lowest slab, and finally removing said apparatus and columns.

After all of the slabs have been erected, the lifting equipment is removed for reuse. To facilitate handling and placement of the wall-columns one or more cranes may be mounted on and ride up with the topmost slab.

According to a second aspect of the invention, there is provided apparatus for constructing a multi-story building from a stack of ground-supported pre-formed horizontal slabs stacked one upon the other and of a length and width to cover a building area and in which each of the slabs has a plurality of lifting column openings vertically aligned in the stack, the apparatus comprising lifting columns arranged for erection in said openings and having a base structure at their lowermost ends for removable ground support of the respective columns, with temporary retaining means associated with the base structure to hold the columns in place while erection proceeds, lifting apparatus arranged for mounting on said columns and operable to lift the stack of slabs up the columns until the lowest slab in the stack has reached a desired elevation above ground level, devices carried on the columns and engageable under the raised lowest slab for interim support of the lowest slab at said desired elevation on the columns so that the lowest slab can be detached from the stack and the lifting apparatus, said lifting apparatus being then operable on the columns to lift the remainder of the stack from the column-supported lowest slab while it is held by said supporting devices at said desired elevation so that while the remainder of the stack is undergoing further lifting by said apparatus, building substructure independent of said columns can be erected under said lowest slab to provide ultimate support for it, and said devices including means for releasing the devices from said lowest slab to attain full support of said lowest slab on said substructure, said lifting apparatus, columns and devices being removable from the erected building for reuse.

The present invention will be more readily understood from the following detailed description of certain preferred embodiments, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a fragmentary top plan view of a stack of precast building deck slabs depicted during the slab pouring or casting operation;

Figure 2 is a sectional detail view taken substantially along the line II—II of Figure 1;

Figure 3 is a sectional detail view similar to Figure 2 but showing a slight modification in the slab making technique and depicting certain additional details;

Figure 4 is a schematic elevational view depicting the assembly preparatory to lifting a stack of horizontal floor and roof deck slabs;

Figure 5 is a similar sectional view depicting an arrangement for doubling the lifting capacity as compared to the arrangement in Figure 4;

Figure 6 is an enlarged side-elevational view taken substantially in the plane of line VI—VI in Figure 4;

Figure 7 is a vertical sectional detail view taken substantially along the line VII—VII in Figure 6;

Figure 8 is an enlarged sectional elevational detail view of one of the take-up nuts employed in the lifting apparatus;

Figure 9 is a vertical sectional detail view depicting the manner in which a horizontal slab is maneuvered in placing it on its supports after it has been raised and released from the bottom of the stack;

Figure 10 is a side elevational view taken substantially in the plane of line X—X of Figure 9;

Figure 11 is an isometric view of a bearing yoke member employed in the slab maneuvering device of Figures 9 and 10;

Figure 12 is an isometric view of a supporting bracket used in the slab handling device of Figures 9 and 10;

Figure 13 is a schematic illustration depicting various features and steps employed in the erection of a building;

Figure 14 is a schematic top plan view depicting the layout of a typical floor slab and angular wall-columns;

Figure 15 is an isometric view showing a precast angular wall-column in course of erection;

Figure 16 is a fragmentary top plan view illustrating placement of grouting gaskets and shims for a wall-column;

Figure 17 is a fragmentary vertical sectional detail view taken substantially along the line XVII—XVII of Figure 16;

Figure 18 is an isometric view of a steel structure angular wall-column;

Figure 19 is a fragmentary vertical elevational view, partially in section depicting the erected relationship of steel frame wall-columns to a floor slab;

Figure 20 is an enlarged top plan view of one form of grouting gasket;

Figure 21 is a similar top plan view of a modified form of the grouting gasket;

Figure 22 is a fragmentary side elevation view of a grouting gasket with an air bleed plate assembled therewith;

Figure 23 is a top plan view of another grouting gasket arrangement; and

Figure 24 is a fragmentary vertical sectional detail view of a building assembly employing the grouting gasket arrangement of Figure 23 taken substantially on the line XXIV—XXIV of Figure 23.

According to the following disclosure horizontal floor and roof deck slabs are poured in situ one upon the other in an area entirely free from columns so that the slabs can be poured and finished by means of mechanical equipment of a generally similar type to that utilized for paving and precasting of sectional and like concrete slabs which are then transported to the building position. This is accomplished by the elimination of the usual permanent building load supporting columns in the building area. To this end, a stack of concrete slabs 25 (Figs. 1 and 2) is successively poured in situ upon a base slab 27 of at least the same total area and which may be a basement slab or a ground level slab as preferred. Suitable footings 28 are provided under the slab 27 and desirably in suitable locations to afford base support for temporary lifting columns to be hereinafter described. Over the footings, the slab 27 is provided at the locations desired with respective wells 29 of adequate dimensions to receive therein respective heavy steel foundation plates 30 each of which rests upon a suitable elastomeric grouting gasket 31. Column anchor bolts 32 extend up from the footing and through respective clearance holes 33 in the plate 30 for receiving the foot of a column.

As each of the slabs 25 is successively poured provisions are made for accommodating slab lifting equipment. Before the first slab 25 is laid upon the base slab 27, a parting agent is coated upon the top surface of the slab 27, and such a parting agent is coated upon the top surface of each succeeding slab so that all of the slabs 25 will be separable. It will be understood that suitable edge forms are also employed.

Since the slabs 25 are not mounted on common vertical columns, the need for attachment and lifting collars in the slabs as in conventional construction is entirely eliminated. Instead, each of the slabs 25 is provided with a simple temporary lifting column clearance opening 34 aligned with the column base well 29 and with each of the openings in the other slabs of the stack. This greatly simplifies structurally efficient placement of reinforcement (not shown) in the slabs.

Where, as shown, the opening 34 is of smaller horizontal cross-sectional dimensions than the well 29, suitable removable filler, such as that rigid foam plastics material commercially available as "Styrofoam" (Registered Trade Mark), pieces 35 may be applied over the foundation plate 30 in the overhanging area of the lowermost slab 25 to maintain the slab thickness and to maintain the well accessible for subsequent removal of the base plate 30 whereafter the well may be grouted closed or utilized for another purpose if desired.

To form the openings 34 during the pouring and finishing of each of the slabs 25, a removable, flat-top box core form 37 is desirably employed which is mounted, for each of the slabs 25, at an elevation flush with the intended top surface plane of the slab to be poured so that it may also serve as a thickness gauge. Such placement of the form 37 is desirably effected by mounting it through respective radially extending spiderarms 38 mounted at their outer ends, as described hereinbelow, upon the upper ends of respective internally threaded coupling sleeves 39 which are screwed onto the upper end portions of respective threaded stub rods 40 resting upon respective spacer sleeves 41 which in turn rest upon respective lifting plates 42 lying flush within the top surface of the underlying slab and mounted to the associated stub rod 40. Under the lowermost of the slabs 25, a lifting plate 42 is recessed within the top surface of the base slab 27 which has respective recesses 43 accommodating the lower end portion of the adjacent stub rod 40 and an attachment nut 44 by which the adjacent plate 42 is secured in place on its stub rod. Preparatory to pouring each of the slabs 25, a core plate 45 on the outer end of each of the spiderarms 38 is aligned with a respective coupling sleeve 39 of one of the four upwardly projecting stub rods 40, with a downwardly projecting alignment boss 47 fitting into the

socket provided by the upper portion of the coupling sleeve. Leveling of the core-forming spider formed by the spiderarms 38 is easily effected by rotary threaded manipulation of the respective couplings 39. Each of the forming or core plates 45 is of the same dimensions as the lifting plates 42 so that after each slab has set and the core forming spider is removed as by lifting it by means of a device 48 attached through a slot 49 in the top of the core form 37, a recess will be provided in the top surface of each of the slabs 25 to receive the lifting plates 42.

Where, instead of the technique described above, i.e. where pouring and finishing the slabs is accomplished with equipment of the generally road paver type, the so called conveyor bridge type of equipment is to be used, longer tension rod sections 50 (Fig. 3) may replace the single slab length sections 40 thus reducing the number of pieces of equipment that need be handled. For example, the sections 50 may be of a length to accommodate four slab thicknesses. Where the longer sections 50 are used, the coupling sleeves 39 need be only at the section joints, while the nuts 44 may be used at all other of the lifting plates 42. An approximately three foot maximum upward extension of the rod sections 50 is tolerable for conveyor bridge slab pouring. Where the rod extensions 50 are employed, the core form 37 may have openings through the forming plates 45 thereof to receive the extensions therethrough, instead of the locating bosses 47 previously described.

After all of the slabs 25 for a particular building structure have been completed and are ready to be erected, namely, after the topmost slab of the stack has been sufficiently cured, temporary steel lifting columns 51 of preferably H-beam section are inserted through the aligned clearance holes 34. Respective foot plates 52, rigidly attached to the lower ends of the columns 51, form a base structure for the columns and are secured to the tops of the respective base plates 30 by means of the bolts 32 onto which are threaded retaining nuts 53 for temporarily retaining the columns in place while erection proceeds. These nuts are placed by any suitable means such as magnetic extension wrenches and tightened lightly. The abutting surfaces of the base plate 30 and the foot plate 52 are desirably milled to make thorough bearing contact. Since the base plate 30 is floatingly supported by the elastomeric gasket 31 thereunder, the full bearing contact is assured between the plates when the column 51 is perfectly vertically adjusted and maintained in such adjustment as by means of suitable wedges 54 inserted between the column 51 and the edge defining the uppermost clearance hole 34 which is made possible because the clearance holes are of sufficiently larger size than the beam section to provide complete clearance about the column. After the column has been thus fixed in its vertical orientation, grout is driven into the space under the base plate 30 within the gasket 31 and supports the column in full load bearing relation upon its footing 28. Introduction of the grout may be through a grout tube 55 delivering through a suitable hole 57 in the margin of the base plate 30.

After the grout under the columns 51 has set to load bearing strength, lifting of the stack of slabs 25 as a unit may be effected upwardly along the columns, and the arrangement is such that the lifting is expedited to the full height of the building by suitable floor-by-floor increments with utmost efficiency, avoiding unduly tall and laterally unsupported columns, without any necessity for dropping lifting rods downwardly to reach for packs of slabs underneath previously raised slabs, and without requiring dismounting of lifting jacks from the tops of columns in order to mount column extensions. To this end, the columns 51 are constructed in substantially one floor sections, being typically of about 8′8″ in length and constructed to be bolted in alignment. Each column section 51 has on its upper end a cap plate 58 (Figs. 6 and 7) upon which is received the foot plate 52 of a superposed aligned column section in full bearing relation with countersunk flatheaded bolts 59 securing the plates fixedly together. It will be understood, of course, that there are as many of the sectional columns as required for efficiently handling the slab span to be lifted.

Initially there is supported on the lower end portion of the second column section a lifting carriage 60 upon which are mounted in balanced lifting relation a pair of hydraulic lifting jacks 61 illustrated schematically in Figures 4, 6 and 7 and for details of structure and operation reference may be had to the aforesaid U.S. Patent No. 2,758,467. Suffice it to say that each of the jack assemblies comprises a holding yoke 62 on which is mounted a hydraulically operating jack unit 63 supporting a lifting yoke 64. Depending freely through the aligned outer end portions of the yokes 62 and 64 are threaded lifting rods 65 secured to the slabs to be lifted and having threaded thereon holding nut assemblies 67 over the yoke 62 and lifting nut assemblies 68 over the yoke 64. Operation of the jack unit 63 causes the lifting yoke 64 to be raised incrementally such as about one-half inch in a typical instance such that the lifting nut assemblies 68 which have theretofore been run down onto the yoke 64 as by means of an operating chain 69, effect similar lifting of the lifting rods 65. Thereupon the holding nuts 67 are run

down onto the holding yoke 62 as by means of a chain drive 70. This lifting cycle is repeated until the lifting rods 65 have raised the slabs the desired distance.

For supporting the jack assemblies 61 in a manner to have the supporting column assume the lifting load in an efficient, balanced relation, the carriage 60 comprises a rugged steel frame having respective opposite coextensive parallel side plates 71 extending to a substantial length beyond the associated column 51 and slidably engaging the side flanges of the column. Extending between and secured to the opposite end portions of the side plates 71 are respective angle bar cross-frame members 72 which provide respective right angular inwardly and downwardly facing reentrant seats into which thrust complementary upper ends of respective supporting brace bars 73 which have their lower ends shaped complementary to an upwardly and outwardly facing seat or shoulder provided by the web of the column 51 and the upper end of a respective shoulder plate 74 fixedly secured to the web.

To enable ready shifting of the carriage 60 from column section to column section, the brace bars 73 are generally hingedly mounted on the carriage. Hinging is effected in a manner to enable full thrusting seating of the upper end of the brace bars in their load carrying function while nevertheless permitting relatively free swinging of the bars into and out of the loading engagement with the respective carriage and column seats when moving the carriage along the column. For this purpose, each of the brace bars 73 has adjacent to its upper end aligned pintles 75 projecting sidewardly and received in respective arcuate clearance slots 77 in the carriage side plates 71 dimensioned to enable swinging of the brace bars downwardly and outwardly as indicated in dash outline in Fig. 7, into clearance relation to the associated column. To facilitate return to and maintenance in the column shoulder seat engaging position, the brace bars are desirably provided with biasing means normally urging them to swing inwardly, herein comprising a respective counterweight 78 mounted on a rigid lever arm 79 extending outwardly from the upper end portion of the bar.

In the operation of the carriage 60, it is mounted on the column assembly, initially supported on the seating shoulders of the second column section in the assembly. All four of the lifting rods 65 are coupled at their lower ends as by means of internally threaded coupling sleeves 80 (Fig. 3) to the upper ends of the stub rod chains mounted in lifting relation to the slabs 25. Then, with the holding nuts backed off from the holding yoke 62, and the lifting nuts 68 run down firmly against the lifting yoke 64, the jack unit 63 is actuated in unison with all of the other lifting jacks which are similarly operatively disposed in respect to the slab stack until the stack has been raised to the maximum height permitted by the initial setting of the carriage 60. Schematically Figure 4 shows the initial phase of lifting the stack of slabs, on comparison of the full outline and dash outline positions.

In order to enable the lifting carriage 60 to be raised to the next higher position on the column assembly and free from the stack of slabs, the stack is held immobile for an interim while the lifting carriages are raised to their next position. For this purpose, holding means are provided at each of the columns, desirably comprising respective holding carriages 81 which in all essential respects are identical and interchangeable with the lifting carriages 60. Inasmuch as the lifting and holding carriages are depicted herein as identical, the same reference numerals are applied to the elements of the carriage 81 in Figure 7 as applied to the carriage 60 and it will be understood that the description of the structure and function of the elements is identical. Since the holding carriages 81 need function only to hold the slab stack in the interim while the lifting carriages are elevated to new positions, the holding carriages are permitted to ride freely on the stack until the respective interim holding positions are reached. As shown in Figure 4, the holding carriage 81 is disposed in position about the column 51 but rests upon the slab stack, being desirably supported on suitable blocks 82 to afford clearance for the downwardly extending brace bars 73. As the slab stack is lifted, the brace bars 73 of the holding carriage 81 may be permitted to idle freely along the web of the adjacent column 51. When the slab stack has been raised as far as practicable by the lifting carriage 60 without resetting the same, the holding carriage 81 will have been brought into substantial alignment with the upwardly facing shoulder provided by the foot plate 52 of the next upper column section. To avoid any necessity for overlifting and then dropping the stack and lifting carriage 81 down into holding position, the holding carriage may be otherwise, such as manually, lifted upwardly relative to the lifting rods 65 until the brace bars 73 automatically snap into seating relation to the foot plate shoulder under their counterweight bias. Then with the carriage 81 supported in holding position on the column assembly, respective holding nuts 83 are run down on the lifting bars 65 firmly against respective holding yokes 84 carried by the holding carriage. Thereby the slab stack load is assumed by the holding carriages 81. This frees the lifting carriages 60 for repositioning upwardly along the column and relative to

the upwardly projecting portions of the lifting rods 65 which have been raised to a sufficient height to be reengaged at the next higher setting of the lifting carriage.

In order to facilitate freeing the lifting carriage in each instance, from the lifting rods, the holding nuts 67 and the lifting nuts 68 are preferably constructed to be freed from the rods so as to avoid having to turn them threadedly up the rods, although that may be done if preferred. In a convenient construction, all of the nuts embody the construction best shown in Figure 8, namely each may comprise a pair of complementary split nut sections 85, such as a standard hexagonal nut cut in half. In operation, a complementary steel shield 87 encompasses the nut sections and holds them in threaded engagement with the associated lifting rod. On the upper end of the shield is a sprocket-toothed collar 88 which is drivingly engaged by the associated drive chain. When the carriage 60 is to be repositioned, the respective nut shields 87 are lifted off of the associated nuts and the nut sections 85 removed from the associated rods 65. After the carriage 60 has been repositioned, the nut asssemblies are reassembled for further operation. Since the split nut structure also facilitates mounting and demounting of the nuts relative to the lifting rods, the holding nuts 83 associated with the holding carriages 81 may embody the same structure if desired.

After the lifting carriages 60 have been repositioned at the next operating level resumption of the lifting cycles of the lifting jacks may be resumed and the lowermost slab 25 in the stack is lifted into a position to be dropped off for its chosen building level. For this purpose the lowermost slab is raised with the stack to an overlifted position wherein its lower face is sufficiently high to afford clearance therebelow and above footings or the next lower slab, as the case may be, to enable erection of load-bearing wall-columns upon the lower slab, whereafter the overlifted slab is lowered into supported relation upon the load-bearing substructure which has been erected thereunder while the slab has been held in the overlifted position for headroom.

While the use of two lifting jack assemblies 61 at each column allows the lifting of double the load of the customary single jack on each column, means may be provided for again doubling the load of slabs to be raised by the present one-shot lift method. For this purpose, the arrangement shown in Figure 5 may be employed wherein in addition to the lifting carriage 60 and the two jack assemblies 61 carried thereby and operating four lifting rods 65, a second and in this instance longer lifting carriage 89 is provided to operate in tandem with the carriage 60. A pair of lifting jack assemblies 90 mounted on the carriage 89 have lifting rods 91 depending therefrom and attached in lifting relation to the upper portion of a stack of precast slabs 25, which may be of the same number as the slabs in the lower portion of the stack to which the jack assemblies 61 are attached through their lifting rods 65. In this arrangement the holding carriage 81 may be of substantially the same length as the lifting carriage 89, and supplied with four holding yokes 84[1] and associated holding nuts, to accommodate all of the lifting rods 65 and 91.

For supporting each successive slab 25 when it reaches its drop-off position, reusable apparatus is provided desirably at each of the columns 51 to afford substantially stress-free support of the slab. In a desirable construction this apparatus comprises, for each column, a supporting device in the form of a three part separable assembly 92 (Figs. 9, 12) arranged to be mounted on the shoulder provided by the foot flange plate 52 of the adjacent column section joint and within the vertical channel space between the side flanges of the column. To this end, the device 92 includes a generally inverted U-shaped supporting yoke bracket 93 having lower outwardly extending supporting ledge lugs 94 and a head 95 extending inwardly on its upper end portion and engageable in thrusting relation from below by a ram 97 of a hydraulic jack 98 arranged to be seated on the supporting shoulder of the foot flange bearing plate 52. A slidable bearing guide is provided by filler member 99 of inverted U shape seated at the lower ends of its vertical legs on the foot plate shoulder and receiving the bracket 93 slidably thereagainst and with ample clearance above the head 95 to enable a full range of operational vertical movement of the supporting bracket 93 under the control of the jack 98.

The construction and arrangement of the supporting device 92 is such that it can be readily installed from below the slab 25 which has been raised to the overlift position shown in dash outline in Figure 9. For this purpose, the filler bearing member 99 is first inserted upwardly into position. The supporting bracket 93 is then inserted upwardly into position within and against the bearing member 99 and held there while the associated jack 98 is placed upwardly into operating position with its ram 97 supportingly under the bracket head 95. Cushions 100 which may be of elastomeric material are desirably interposed between the supporting lugs 94 and engage the undersurface of the slab 25. It will be observed that for maximum stability and stress-free operation, two devices 92 are associated with each column. Suitable hydraulic control means are provided for operating the jacks 98

and may comprise manual pumping and release means for each pair of jacks or the jacks on all columns may be connected for operation in unison. Initially the jacks 98 are operated to effect a lifting thrust on the engaged slab 25 sufficient to enable releasing the slab from the lifting rods 65 or 91, as the case may be, by detaching the lifting plates 42 from beneath the slab which is now supported by the brackets 93. Thereupon the remainder of the stack of slabs 25 above the released slab can be lifted on toward dropping off of the next succeeding lower slab. In the meatime, supporting substructure is erected under the stationarily held slab 25 while the remaining slabs may continue their upward travel.

By virtue of the lifting of the total stack of floor and roof slabs, and the freedom under the lowermost slab for building erection activity as soon as it has reached its headroom overlifted position, of the order of six inches above final position in the building, work on the floor area under such lowermost slab can proceed immediately and without interruption while the temporary supporting device 92 is placed on the columns, the slab is released from the bottom of the stack and lifting of the remainder of the stack continues. This lends itself exceptionally well to rapid placement of prefabricated load-bearing wall-columns 101 on the floor deck or footings, as the case may be, below the over-lifted slab, whereafter such slab is lowered into supported relation on the wall-columns 101 by retraction of the jack rams 97, to the full line position shown in Figure 9. With the slab load thus transferred from the holding jacks 98 to the load-bearing substructure, the devices 92 can be released from the slab and removed for reuse. Such removal is easily effected by removing the filler bearing members 99 upwardly, swinging the brackets 93 from the lower unloaded position shown in dot-dash outline in Figure 9 to clear the supporting lugs 94 into the vertical channel of the column and pass the slab while the bracket is withdrawn upwardly. Thereafter the jack 98 may also be withdrawn upwardly for reuse. After each floor slab has been mounted and the temporary or interim supporting device 92 has been removed, stabilizing wedges 102 (Fig. 13) which may be hardwood, may be driven into engagement between the lifting columns 51 and the erected horizontal slab 25 to provide lateral stability for the columns taking advantage of the great lateral stability inherent in the building structure of which the slab is now a part.

To assist in the erection of the preformed load-bearing wall-columns 101, a ground-supported crane may be used, but because of the highly stable, large load capacity means for lifting the stack of slabs 25 herein, a crane 103 is adapted to be mounted on the uppermost or roof slab 25, as by bolting the same thereto. Thereby the ground area around the building is left relatively free for other purposes, and the top mounted crane is constantly available for lifting materials including the wall-columns 101 to each floor space as it becomes available. On the floor on which the wall-columns 101 are to be mounted, forklift truck means or dollies may be utilized for moving the wall-columns into position.

By having the preformed load-bearing wall columns 101 of angular shape (Fig. 14) they may be set into place to be both stable and plumb without any type of temporary bracing. After they are grouted-in between the slabs below and above, they furnish shear walls in two directions and make the building immediately laterally stable, up to the level of the slab above the wall. These angular wall-columns furnish moment stiff connection at all slab supports even in the exterior slab corners. This moment connection is provided with very little reduction in the vertical carrying capacity of the wall-column. This result accrues from the fact that there is no bending about a weak axis in any of the wall-column units. The moment stiff connection along exterior walls enables great savings in slab design and greatly reduces damaging deflections in the slab and slab edges as compared to conventional column supported slabs.

Where the horizontal slabs are supported on columns extending therethrough as has been conventional practice, the slabs are subjected to large peak moments at the columns and these moments largely control the selection of the required slab thickness and the amount of reinforcing steel therein. In post-tensioned slabs, these conditions are even more pronounced because of the need to carry the same steel tendon through negative and positive bending zones from one edge of the slab to the opposite edge. By using the angular preformed wall-columns negative peak moments are greatly reduced and large savings in material and labor are permitted. Another decided advantage of the angular load-supporting wall-columns is that fireproofing is substantially facilitated and enhanced, especially where such columns are of precast concrete as compared with conventional steel columns. Typical arrangements of the angular wall-columns 101 are schematically depicted in Figure 14 on a large area floor slab 25 and demonstrate the great versatility of this mode of construction. The great architectural design latitude as to floor plan and wall treatment is readily apparent. Exterior walls, partitions, enclosures and reinforcement about elevator shafts 104, stairwells 105, utility openings 107, and the like in the floor slab are readily accommodated.

Location of the temporary column clearance openings 34 in the slab can be readily related to the predetermined positions desired for the wall-columns 101 to avoid interference with placement of the columns and yet provide for substantially strain-free lifting and handling of the slab in the manner already described.

In order to secure full and uniformly distributed load-bearing by and onto the angular wall-column 101 in each instance, a three-point post assembly injected grouting arrangement is provided for, utilizing the same general method and arrangement hereinbefore described in respect to providing a thorough supporting base for the temporary lifting columns 51. To this end, as shown in Figures 15, 16 and 17, grout-retaining elastomeric gaskets 108 are positioned between the ends of the wall-column and the confronting slab 25 at preferably three areas, namely adjacent the respective opposite ends of the end edge areas and adjacent the convergence of the end edge areas. Lead gauging shims 109 are desirably placed between the column edges and the slabs adjacent to but outside the quadrangular grout gaskets 108. Such shims are of a thickness sufficiently less than the thickness of the gaskets 108 to permit adequate sealing compression of the gaskets, but avoiding collapse of the gaskets beyond useful grout-receptive thickness. Grout is then filled into the areas within the gasket under pressure to afford a desirable density and load-bearing capacity of the set grout. Any remaining gaps between the ends of the wall-columns 101 and the slabs may be grouted or calked.

Instead of precast reinforced concrete construction for the wall-columns, a prefabricated metal angular wall-column 110 (Figure 19) may be employed. In a typical construction, the wall-column 110 comprises three substantially identical vertical posts which may be of H-beam configuration rigidly connected together coextensively in the preferred spaced relatively angular column outline by horizontal bars 112 and diagonal brace bars 113. On the respective opposite ends of the posts 111 are rigidly affixed coplanar bearing pad flange plates 114. In mounting the metal frame wall-columns 110, elastomeric grout-retaining ring gaskets 115 are interposed between the bearing pads 114 and respective metal bearing plates 117 mounted in the confronting faces of the floor slab 25. Respective spacers 118 are preferably disposed between the column units 110, and within the areas confined by the gaskets 115 if desired, and the slab 25 or other load-engager surfaced in order to maintain a desired depth of grout space within the gaskets 115. After erection of the floor slabs and metal frame wall-columns has been effected, any desirable wall covering 119 may be applied onto and over the columns and over the exposed edges of the slab 25, as preferred.

In loading grout into any of the gasket-enclosed areas under the column base, and between wall-columns and the slab surfaces, not only are means for injecting the grout required but also means for venting air and water to prevent formation of pockets or voids. In one arrangement as depicted in Figure 20, the elastomeric gasket G in angular ring form in order to present a quadrangular enclosure for maximum efficiency in the generally quadrangular bearing areas of the respective load-bearing members, may be provided through one corner thereof with a charging hole 120 provided with a semi-rigid, but resilient reinforcing liner 121 to prevent collapse under pressure and through which discharges a loading hose 122 attached to the gasket and connected with a suitable low pressure grout pump or injector. Extending from within at least the remaining corners of the gasket to the exterior are vent means comprising small diameter bleed tubes 123. After the assembly has been completed and the gasket placed under limited compression between the parts to be grouted, grout is injected through the hose 122 until fluid constituents thereof bleed from each of the bleed tubes 123 which may be successively pinched off as the bleed be successively pinched off as the bleed-out is observed, as by means of a suitable respective clamp 124. After the gasket-enclosed area has been filled with grout, the charging tube 122 may be pinched off as by means of a clamp 125 to avoid regression of fluent grout. After the grout has set, the tube 122 may be cut off close to the gasket G, as indicated at S.

In another arrangement, as shown in Figure 21, the gasket loading tube 122 may be fixed within the reinforcing liner 121 and provided with a pressure bulb 127. As the gasket area is loaded with grout and back pressure develops the bulb 127 expands as shown in dash outline and, being of elastomeric material, the resiliency maintains the grout under pressure while it is setting and after the tube has been pinched off as by means of the clamp 125 applied to the loading tube outwardly beyond the pressure bulb 127. As an alternative to bleed tubes, the gasket G may be provided with bleed grooves 128 extending across the corner areas on at least one side of the gasket from the inside to the outside and of such shallowness that although air and water will be permitted to escape, when grout material enters the grooves they will be sealed off so that a self-sealing relationship is attained after air and water has been ejected from the grout area.

Where it is desired to maintain positive

bleed passage groove openings even though the gasket may be liable to substantial pressures which might prematurely close off bleed grooves in the actual surface of the gasket, the structure shown in Figure 22 may be employed comprising a bleed groove plate 129 which may be made from rigid or semi-rigid plastics or metal and has on its exposed surface bleed grooves 130 while the opposite surface is engaged against and may be compressed into the confronting surface of the gasket. If desired the bleed plate 129 may be adhesively or otherwise secured to the gasket. At its sides, the plate 129 may be chamfered as shown to avoid cutting into the gasket under pressure.

Where it is desired to effect not only bearing uniformity by means of the grout, but also to provide moment continuity, means may be provided for distributing the grout in keying relation to the grouted structural members. Such an arrangement is shown in Figures 23 and 24 wherein the gasket encompasses an area within which one of the members has a keying recess 131 to which leads a grouting passage 132 from the outside receptive of a grout delivery hose 133. From the other of the members there extends into the recess 131 a key projection 134 which remains in spaced relation to the surfaces defining the recess 131 such that when grout is injected into the space around the key and into the gasket enclosed area the key will be set and interlock the members against lateral displacement pressures or stresses. Additional keying may be effected by providing the members with sleeves or aligned core bosses 135 within which a dowel 137 of smaller diameter is placed and the grout fills into the bores and about the dowel so that a thoroughly keyed structure results. Bleed off may be effected in a preferred manner such as by means of bleed ducts 138 bleeding through one or more of the building members to the outside and which ducts are self-sealing due to their length and the relative clogging nature of the grout material in respect to small openings. Similar bleed ducts 139 may lead from the dead ends of the keying bores 135. If desired, either or both of the grout delivery tubes 133 may be provided with the expansible pressure bulb 127. Further, either or both of the delivery may be pinched off as by means of the clamp 125 if desired to prevent regression of the grout load.

The gaskets G may be made from any suitable elastomeric material such as neoprene. In order to facilitate placement and retention of the grout gaskets during handling of the building parts and placement thereof, the gaskets may be adhesively secured to the surface on which first mounted. For example, where the gaskets are mounted on a slab surface, they may be adhesively secured thereto in the desired position. Where they are mounted on wall-columns, they may be adhesively secured thereto. As delivered to the building site, the gaskets may be provided on one surface with a pressure sensitive adhesive and with a suitable protective cover thereon which is stripped off before the gaskets are applied, according to known practice in the use of such pressure sensitive adhesively coated members.

After all of the precast slabs have been litfed to their final locations and set upon their supporting substructures, all of the stabilizing wedges and hardware employed in the lifting operation, including the lifting jacks, lifting and holding carriages, lifting rods, stub rod chains, couplings, lifting plates, lifting nuts, intermediate holding and handling apparatus, sectional lifting columns and their base plates are removed from the building for reuse at another building site.

WHAT I CLAIM IS:—

1. A method of constructing a multi-story building, comprising pre-forming on a ground-supported base a stack of horizontal slabs one upon the other and of a length and width to cover a building area, providing in each of said slabs a plurality of openings vertically aligned in the stack, erecting in said openings ground-supported lifting columns, mounting lifting apparatus on said columns, operating said apparatus to lift said stack of slabs along said columns until the lowest slab in the stack has reached a desired elevation above said base, supporting said lowest slab at said desired elevation on said columns and detaching it from the stack and said lifting apparatus, further operating said lifting apparatus on said columns to lift the remainder of the stack from said column-supported lowest slab while it is held at said desired elevation, while said remainder of the stack is undergoing further lifting by said apparatus erecting building substructure independent of said columns under said lowest slab to provide ultimate support therefor, releasing said lowest slab from said columns on to said substructure for full support by said substructure, repeating the foregoing procedure with each succeeding lowest slab, and finally removing said apparatus and columns.

2. A method according to claim 1, wherein said desired elevation is in overlift relation to the building substructure, and wherein said releasing of the lowest slab comprises depositing the slab from said elevation downwardly on to said substructure.

3. A method according to claim 2, comprising preforming said substructure and erecting said substructure by moving it into position under said lowest slab.

4. A method according to claim 3, comprising pre-forming said substructure in the

form of a plurality of angular wall-columns, and erecting said wall-columns by moving them into efficient respective load-bearing positions under said lowest slab.

5. A method according to claim 4, wherein said wall-columns have opposite end bearing faces, comprising locating said wall-columns at desirable locations under said lowest slab, and placing between at least the bearing faces of said wall-columns confronting said slab means for assuring a balanced load-supporting relation between wall-columns and said slab.

6. A method according to claim 5, comprising placing retaining gaskets between said bearing faces and said slab, lowering the slab on to the gaskets, and filling the spaces between the slab and the bearing faces within the gaskets with grout to assure stable and efficient load distribution on to the columns.

7. A method according to claim 6, comprising placing load-bearing shims between said bearing faces and said slab to prevent collapse of said gaskets.

8. A method according to claim 1, comprising mounting base plates under said columns, and grouting under said base plates to assure balanced vertical load distribution.

9. A method according to claim 8, comprising mounting said base plates on retaining gaskets, mounting said columns on the base plates, holding said columns in vertical orientation with the base plates normal to the vertical axes of the respective columns, and filling grout under the base plates in the spaces defined by the gaskets and then setting the grout to maintain said balanced load distribution.

10. A method according to claim 6, 7 or 9, comprising bleeding air through a passage leading from each said retaining gasket.

11. A method according to claim 10, comprising bleeding the air through a passage extending across each retaining gasket or through each retaining gasket.

12. A method according to claim 6, 7 or 9, comprising filling the space within each retaining gasket through a passage extending through one of the opposed surfaces against which the gasket engages.

13. A method according to claim 10, comprising bleeding air from within each retaining gasket through a passage extending through one of the surfaces against which the gasket engages.

14. A method according to claim 6, 7 or 9, comprising placing a grooved plate on each retaining gasket and bleeding air through grooves in the plate.

15. A method according to claim 6, 7 or any one of claims 9 to 14, comprising inserting a dowel within aligned bores in the surfaces engaged by each retaining gasket and on an axis within the areas of the gasket and with clearance about the dowel, and filling grout into the bores to lock the dowel and effect a thoroughly keyed structure.

16. A method according to claim 6, 7 or any one of claims 9 to 14, comprising extending a key projection from one of the surfaces engaged by each retaining gasket into a clearance recess in the other of the surfaces engaged by such gasket, and filling the clearance with grout to thereby interlock the surfaces against lateral displacement stresses.

17. A method according to any preceding claim, comprising mounting a crane on the uppermost slab in the stack, and operating said crane to deliver substructure units to the floor area under said slabs after they have been lifted to their desired elevations.

18. A method according to any preceding claim, comprising wedging said columns to at least certain of said slabs after they have been released into full supporting relation to their substructures to stabilize the columns.

19. A method according to any preceding claim, comprising removably mounting in the slabs adjacent each of said openings a plurality of vertical slab connecting lifting rod extension elements having their upper ends above the top-most slab for coupling thereto of lifting rods of said lifting apparatus carried by said columns and removably securing lifting plates on said lifting rod extension elements under each of the slabs whereby all of the slabs can be lifted in unison and then each lower slab can be released successively from the bottom of the lifted stack.

20. A method according to claim 19, comprising supporting for each slab to be formed a hole core and lifting plate socket forming spider as a thickness gauge on said extension elements above the surface upon which the slab is to be formed.

21. A method according to any preceding claim, comprising mounting the lifting apparatus on said columns at a height which is sufficient to enable lifting the entire stack to adjacent said desired elevation, connecting lifting rods to the slabs in the stack and attaching the lifting rods to said lifting apparatus, actuating the lifting apparatus to raise the rods and thereby lift the stack to adjacent said elevation but with a clearance space between said lifting apparatus and said stack, mounting on the columns respective holding carriages within said space and connecting said carriages to said rods in load-supporting holding relation to thereby support the stack from said carriages, disconnecting said lifting apparatus from said rods and relocating the apparatus on the columns at a second height near the elevation to which the next succeeding lower slab is to be raised, then reconnecting the lifting apparatus to said rods for operation to continue lifting of the stack and disconnecting said holding

carriages, continuing lifting of the stack until the lowest slab has reached said desired elevation, whereafter the lowest slab is supported on said columns.

22. A method according to claim 21, comprising supporting said carriages on top of the stack to ride upwardly therewith adjacent said columns when the carriages are not mounted on the columns or attached supportingly to said rods.

23. A method of constructing a multi-story building according to claim 1, substantially as herein described.

24. Apparatus for constructing a multi-story building from a stack of ground-supported pre-formed horizontal slabs stacked one upon the other and of a length and width to cover a building area and in which each of the slabs has a plurality of lifting column openings vertically aligned in the stack, the apparatus comprising lifting columns arranged for erection in said openings and having a base structure at their lowermost ends for removable ground support of the respective columns, with temporary retaining means associated with the base structure to hold the columns in place while erection proceeds, lifting apparatus arranged for mounting on said columns and operable to lift the stack of slabs up the columns until the lowest slab in the stack has reached a desired elevation above ground level, devices carried on the columns and engageable under the raised lowest slab for interim support of the lowest slab at said desired elevation on the columns so that the lowest slab can be detached from the stack and the lifting apparatus, said lifting apparatus being then operable on the columns to lift the remainder of the stack from the column-supported lowest slab while it is held by said supporting devices at said desired elevation so that while the remainder of the stack is undergoing further lifting by said apparatus, building substructure independent of said columns can be erected under said lowest slab to provide ultimate support for it, and said devices including means for releasing the devices from said lowest slab to attain full support of said lowest slab on said substructure, said lifting apparatus, columns and devices being removable from the erected building for reuse.

25. Apparatus according to claim 24, comprising a carriage movable vertically along each column and having means engageable with the associated column to maintain the carriage at a substantial height above the uppermost slab and leaving the top of the associated column free for mounting thereon a column extension as needed, and lifting means supported by each of the carriages and having means detachably connectable to the slabs for lifting the slabs upon operation of the carriage supported means.

26. Apparatus according to claim 25, wherein said columns have upwardly-facing supporting shoulders thereon at predetermined heights and said carriages have respective shoulder engaging means whereby the carriages are retained in load-supporting position on the columns.

27. Apparatus according to claim 26, in which said column engaging means comprise releasable brace members enabling the carriages to be moved freely upwardly on the columns and extensions of the columns into successively higher positions on the columns.

28. Apparatus according to claim 25, 26 or 27, wherein each of said carriages extends a substantial distance on opposite sides of the associated column and each opposite end portion of each of the carriages has slab-lifting means thereon.

29. Apparatus according to claim 25, 26, 27 or 28, comprising a second carriage under each said first-mentioned carriage and serving as a holding carriage and having means thereon for engagement with the associated column and with said slab-lifting means of the carriage thereabove for retaining the slabs at an elevated position to which lifted by said lifting means while said first-mentioned carriage is raised to a higher position.

30. Apparatus according to any one of claims 24—29, wherein said interim supporting devices are engageable with said columns after said lifting means have lifted the lowest slab to the desired elevation to support it on detachment from the lifting means, and said devices are removable from the columns for re-use after release from the substructure-supported lowest slab.

31. Apparatus according to claim 24, wherein said interim holding devices comprise assemblies separably mountable on the respective columns after the respective lowermost slabs have been lifted to substantially their desired elevations, means on said assemblies for engaging and supporting the lowermost slab with which associated by transference of the slab load to the columns, and said releasing means being operable to release said engaging and supporting means after the supporting substructure has been erected under the slab.

32. Apparatus according to claim 31, wherein each of said engaging and supporting means comprises a lifting bracket, and said releasing means comprise a lifting jack also operable to provide lifting ability for said bracket.

33. Apparatus according to claim 32, in which each of said assemblies includes a removable back-up bearing member for said bracket and serves as a filler behind the bracket enabling removal of the bracket from the column and the slab upon removal of the bearing member.

34. Apparatus according to any one of

claims 25—33, having said columns in one storey building height sections, means for securing said column sections vertically end-to-end, means on lower portions of said sections providing seats including upwardly facing shoulders, and means on said carriages separably engaging said seats in load bearing relation.

35. Apparatus according to claim 24, in which said lifting apparatus comprises tandem carriages mounted one above the other on the columns, a respective plurality of jacks mounted on each of the carriages, and lifting rods connected to the slabs and respectively engaged to be raised by the jacks.

36. Apparatus according to claim 35, including respective holding carriages supported by said columns under said tandem carriages and having means for holding engagement with all of the lifting rods of the tandem carriages.

37. Apparatus for constructing a multi-storey building according to claim 24, substantially as herein described with reference to the accompanying drawings.

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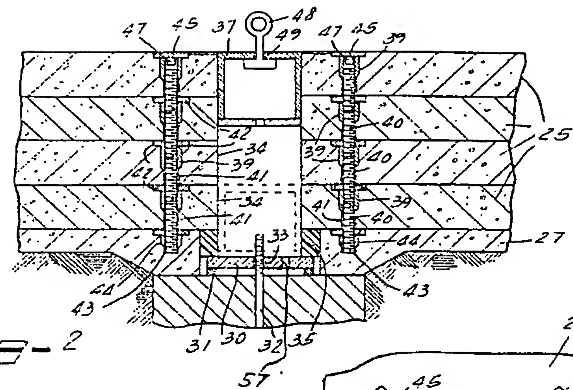

Fig. 2

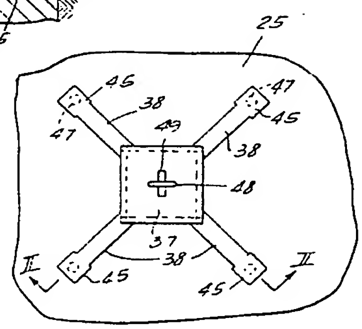

Fig. 1

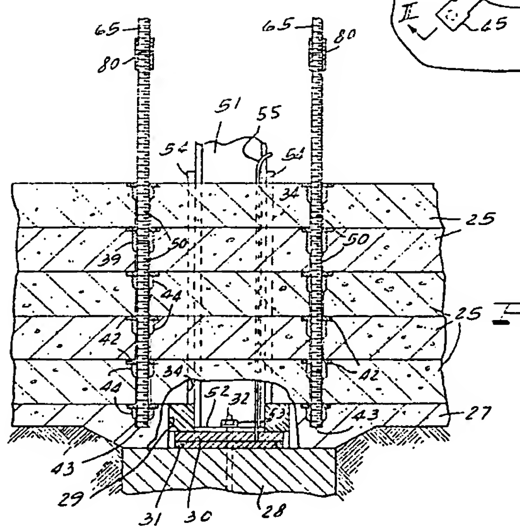

Fig. 3

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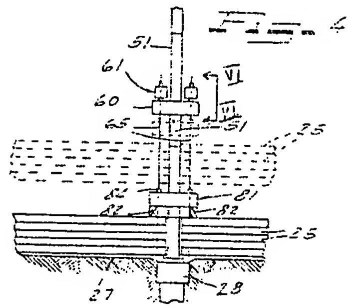

Fig. 4

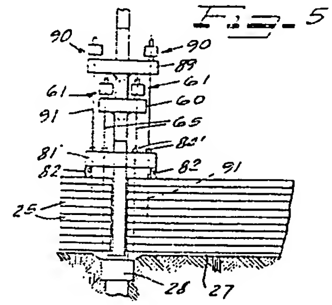

Fig. 5

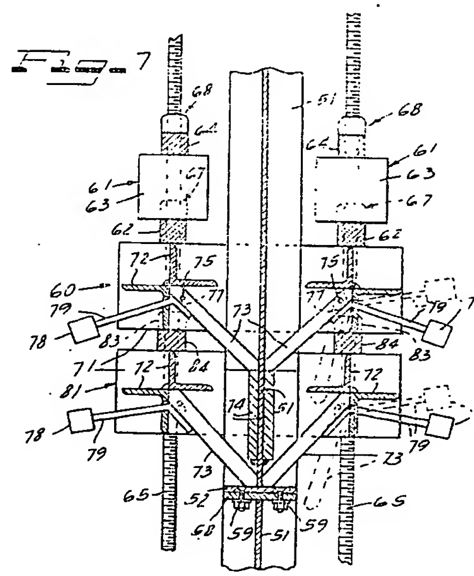

Fig. 7

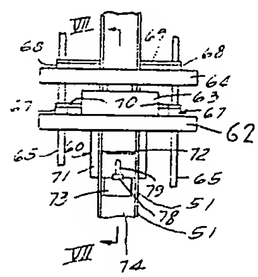

Fig. 6

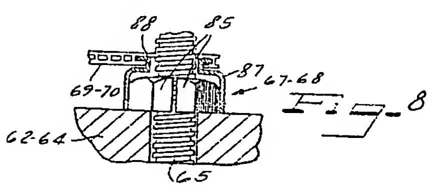

Fig. 8

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Sheet 3

Fig-9

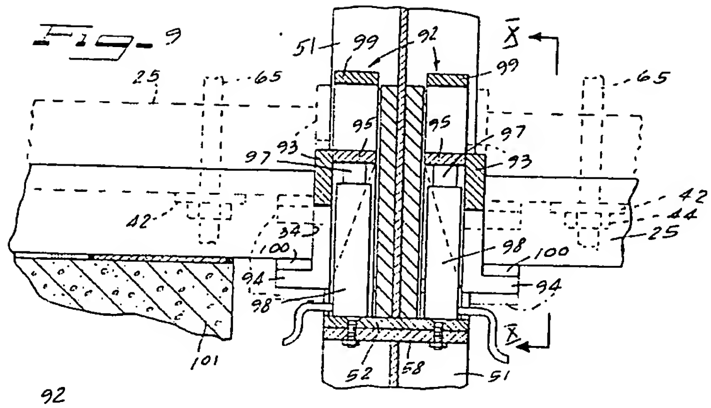
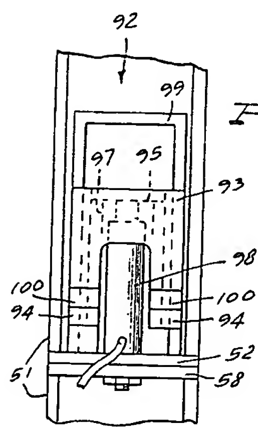


Fig-10



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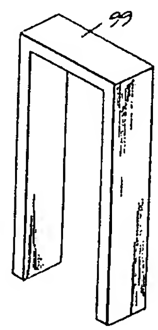

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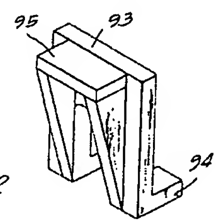

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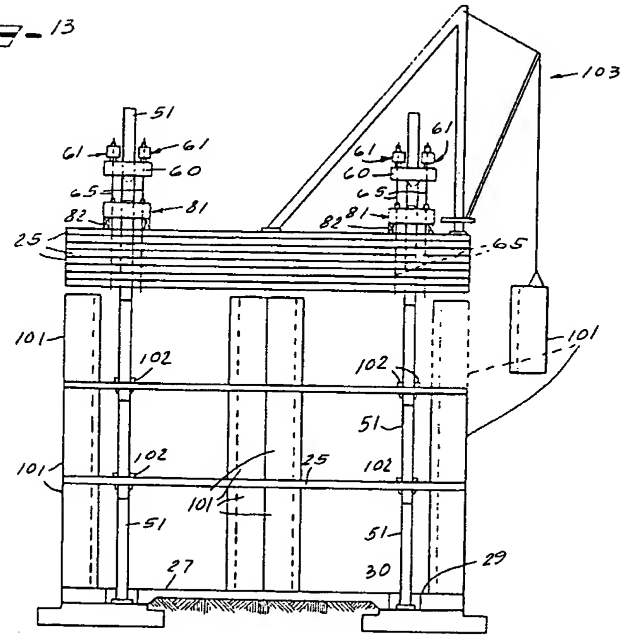
Fig-13



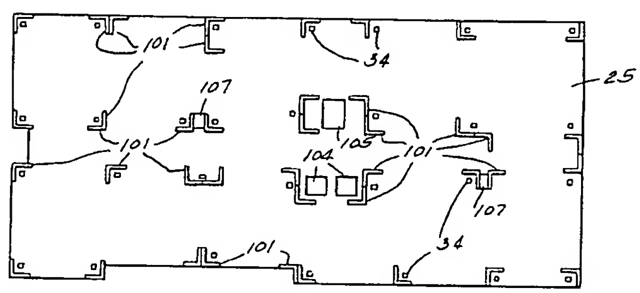


Fig-14

Fig. 15

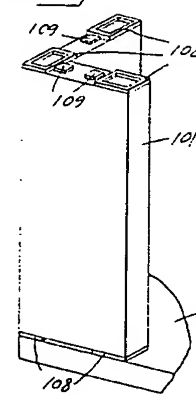


Fig. 18

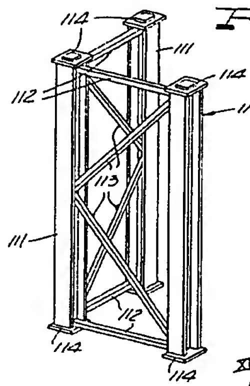
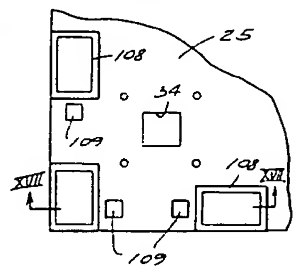


Fig. 16



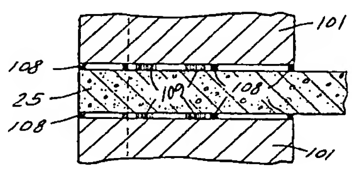


Fig. 17

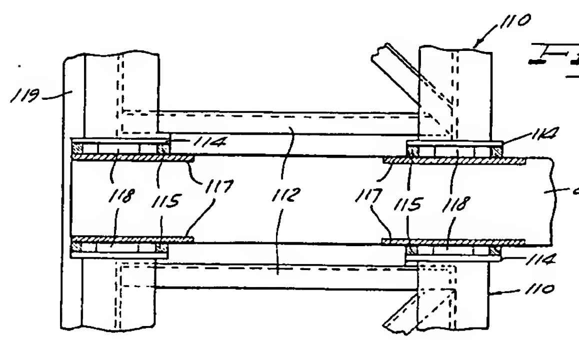


Fig. 19

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Sheet 6

Fig. 20

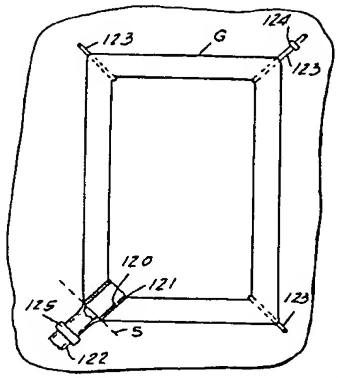
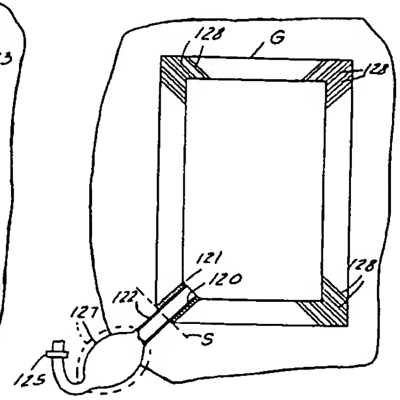


Fig. 21



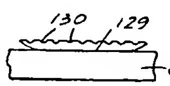


Fig. 22

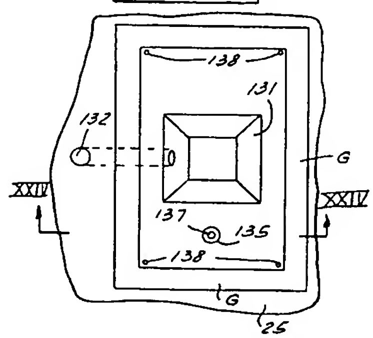


Fig. 23

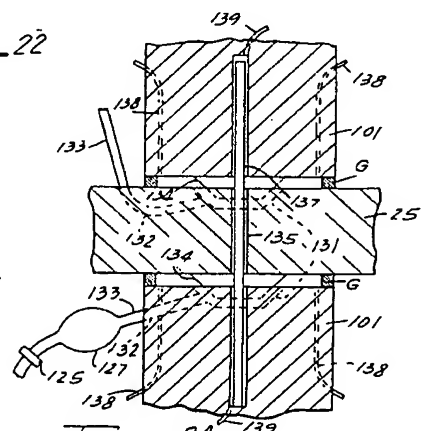


Fig. 24

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